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AUTHOR	Holliday, William G.; Benson, Garth D.
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ABSTRACT

A study is presented which utilizes a selective attention model to investigate the learning effects of different questioning strategies under four experimental conditions using a non-prose medium (science textbook chart) containing information of varying established difficulty. A 14-row, 4-column chart describing 14 vitamins was used to present four characteristics as established in pre-experimental study. Questions derived from the chart were paraphrased and randomly assigned in a counter balanced fashion to sub-groups of students within each group. A sample of 299 high school biology students enrolled in two high schools was randomly assigned to five treatment-control sub-groups. Findings are reported relating to students' being permitted to inspect the posttest before administration, to the importance of emphasis on study questions, and to variations in methods of focusing attention. (CS)

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Using a Chart-table Medium to Focus Students' Attention on Science Concepts

William G. Holliday
Garth D. Benson
The University of Calgary

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The purpose of this research study was to evaluate the generalizability of student attending hypotheses (previously evaluated using texts) to the teaching of science concepts using a chart-table medium. Reading research of late clearly suggested that questions presented with texts can focus students' attention on different aspects of material resulting in achievement facilitation or inhibition (Holliday, 1980). Theoretical (Bransford, 1979) and empirical (Ellis, Wulfeck and Montague, 1980) research confirmed the importance of questions as a good way of focusing students' attention on selected portions of the printed page. Such findings have prompted research people: (1) to use textbook study questions (usually answered during or after the reading or reviewing of a textbook chapter) for the purpose of directly identifying and quantifying variables that maximize comprehension and (2) to use postquestions (always answered after reading a small portion of learning material - student review of read material was never permitted) for the purpose of understanding how students attend to and process different kinds of information. Both research approaches have yielded useful information for designers of science textbooks (Holliday, in press; Wilson and Koran, 1976). A goal of the present postquestion study was to extend this line of inquiry from a text medium to a science chart-table medium which often supplants verbs and modifiers found in texts with

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diagrammatic matrices used to accent and delineate verbal and visual attributes of concepts.

Recent studies (Reynold, Standiford and Anderson, 1979; Sefkow and Myers, 1980) demonstrated that postquestions inserted periodically throughout text materials improved students' recall of information which postquestions directly addressed (i.e., posttest items matching or equivalent in content to postquestions). In addition, postquestions improved to a lesser degree recall of information which postquestions indirectly addressed (i.e., posttest items querying similar but not the same information asked in the postquestion). These so-called direct and indirect learning effects produced by postquestions were used to explain how students processed information. On the one hand, the direct effects of postquestions were helpful in explaining how study questions can influence student directed attentional processing of textbook material. On the other hand, the indirect effects helped to explain how such direct attention influences students' focusing behavior on information related to postquestions, and students' comprehension of wholly unrelated information in the same text - thus, not directly controlled through questioning by teachers or authors of school materials. Indirect effects in particular have been attributed by some (Reynold, et al., 1979) to a selective increase in student attention to the text materials encountered after the presentation of an inserted postquestion. This explanation is referred to as the forward shaping hypothesis. In addition, indirect effects have been characterized by others (Rickard, 1979) as stimulus for review by students of previously encountered portions of text. This explanation is referred to as the backward shaping hypothesis. The correct combination of explanations has not yet been confirmed by empirical data. Nevertheless, the study of indirect learning effects has clarified theoretical issues in reading and stimulated additional postquestion research experiments run under more closely controlled conditions. In recent studies, researchers (Reynold et al., 1979; Sefkow et al., 1980) have used improved designs resulting in increased chances of text information being available in student memory to be reviewed yet not so well learned by students that a review brings little benefit to learners provided postquestions. In the present study a balance was also sought by limiting participants' exposure to learning material while inserting questions frequently.

Hypotheses in this study were based on previous postquestion results dealing with the text medium and on research work reviewed by Winn and Holliday (1981) dealing with diagrammatic media in science education. In combination, these findings suggested that both direct and indirect learning effects produced by postquestions probably were greater when students were presented selected concepts and their attributes using a diagrammatic chart-table medium rather than a text. Apparently, arranging clearly definable attributes of concepts into the diagrammatic matrices of a chart-table can increase attention of conceptual attributes (Holliday, 1976, in press; Winn and Holliday, 1981) while reducing the readability load on the learner (Holliday and Braun, 1979). Thus, it was hypothesized in this study that inserting postquestions into a chart-table would increase learner recognition of concept attributes within each postquestion target category while decreasing learner recognition of attributes outside the target category - that is, outside the information domain of inserted postquestions.

Direct effects were predicted to be more powerful than indirect effects but not to the same degree found in popular pre-1970 studies using a text medium. The fact is neither effect is well established by the current literature, contrary to claims made by Anderson and Biddle (1975) and Reynold et al. (1979). Nevertheless, both effects seemed to be more prevelant in learners familiar with the task. In theory, the nature of task structure was clearly established and unambiguous when learners were required to repeat the task often and when learners' expectations regarding criterial performance were clarified through explanation and practice, according to McConkie's (1977) review of the literature. Previous studies seldom permitted learner practice in answering postquestions and never described the criterial tasks nor provided practice of any kind. In the present study it was hypothesized that the chart-table medium augmented direct and indirect learning effects providing learners were familiar with the reading-answering postquestion task (and with the nature of the posttest criterion) because the language used in the chart-table was highly abbreviated relative to a text and was arranged on the page in a way that expressed the logical relationship among concepts and their attributes - by means of spatial layout rather than through syntax. As a consequence, it was hypothesized that control of learners' attention

was more effective when teaching simple attributes of concepts using chart-table medium. In addition, learners provided with postquestions covering a category of concept attributes were more likely to focus on the target category and less likely to attend to other non-target categories because of the ease of differentiating target from non-target information as displayed in a chart-table. In other words, students provided with focusing postquestions were predicted to benefit from the compartmental features of a chartable medium relative to a text. On the other hand, students, provided with no postquestions or non-focusing postquestions covering all categories, were expected to pay equivalent attention to all categories of displayed information because the task without focusing postquestions did not suggest certain information categories (targeted or not targeted concept attributes) were more or less important to the learner, as argued by McConkie (1977).

Second, this study examined the effects of manipulating orienting directions to students. McConkie (1977) stated that students were often unfamiliar with the task structure imposed on them while engaged in postquestion experiments. He cited task ambiguity on the part of the learner as the main reason for unordered patterns in postquestion data studies. Similar patterns were identified by Rickard (1979). Specifically, McConkie (1977) hypothesized that students unclear about the nature of the posttest or the meaning of the postquestion likely reacted to these unusual experimental materials in different ways which may have resulted in inconsistent findings among similarly structured research studies. In the present study, student directions or knowledge about the postquestions and the posttest was described to students in various ways and was altered in an attempt to support McConkie's (1977) argument. This was done by describing some aspects to all students about the character of the postquestions and the posttests while providing still more information about the nature of the postquestions and of the posttest to different subgroups of students.

METHOD

Materials. Fourteen vitamins including four of their attributes were identified and used as a basis in the development of the science instructional chart-table. The two "source" attributes consisted of

"one name" and "one food" and the two "effect" attributes consisted of one physiological function ("can help produce healthy") and one disease-symptom ("lacking or too little can produce unhealthy"). The chart consisted of five columns beginning with "vitamin letter" at the upper left corner and followed to the right by two subordinate attribute categories within each of the two superordinate categories labeled at the top of the chart-table and above their respective attributes. The first and third attributes were described using one word and one or two words were used to describe the second and fourth attributes. None of the attribute words were repeated. Specifically, column one contained 14 vitamin letters (i.e., A, B_2, ... E, K). Column two contained 14 names (i.e., carotene, thiamine, ... tocophenol, napthoquinone). Column three contained 14 foods (i.e., red peppers, organ meat, ... margarine, alfalfa sprouts). Column four contained 14 healthy tissues of vitamin abundance (i.e., lungs, muscles, ... skin, liver). Column five contained 14 diseases of vitamin deficiencies (i.e., night blindness, appetite loss, ... cell breakdown, internal bleeding).

The 56 (14 by 4) attribute values were chosen on the basis of biological fact and apparent unfamiliarity of vitamin-attribute association among the students. Thus, this content structure increased the chances of students merely recalling specific associations from previous school training. Second, the attribute information was chosen on the basis of the source attributes being more easily learned and the effect attributes being more difficult-to-learn. This difference was established in a pilot study and was used to support the focusing hypotheses in a more cogent fashion, as argued in the results and discussion sections of this paper.

The described chart was used as a basis for developing the treatment charts - displaying one vitamin row at a time followed by a single post-question, as was the established procedure used in other mathemagenic studies (Rickard, 1979). In other words, one postquestion appeared after each row of vitamin information was presented to all treatment groups. Fifty-six treatment postquestions and 14 placebo postquestions were developed for this study. Postquestions were counterbalanced in all instances and randomly assigned to each student within each treatment. The treatment postquestions asked for attribute information from one of the

four columns (e.g., "The name of vitamin A is?") and the 14 placebo postquestions asked for general knowledge information totally unrelated to vitamins to prevent proactive and retroactive learning inhibition. The attribute question type was used to establish the influence of interrogatives on student attending processes. The unrelated question type was used as a placebo-control, as recommended by Faw and Waller (1976).

The posttest evaluated students' recognition of the last seven vitamins presented during instruction and consisted of one sheet of paper with the top half containing an empty seven-by-four vitamin chart matrix and the bottom half containing four lists of seven attributes each. The 28 removed attributes (14 name-food source and 14 healthy-unhealthy effect items) were placed in alphabetical order below the four respective columns of the empty chart. The students' task was to fill each cell of the chart using the words in the column list directly below the cell in question. This recognition task was used rather than a recall task to reduce task difficulty and to increase the ease of students recognizing the vitamin names, many of which were unfamiliar to students. A similar technique was used by Winn (1980) in his diagrammatic study.

Design and Procedure. Students were randomly assigned to four special orientating directed groups (1. no intervention, 2. posttest exposure, 3. postquestion emphasis and 4. combined intervention). Subsequently, students were randomly assigned to a control and four postquestion treatment groups (1. none-related postquestions, 2. source focusing, 3. effect focusing and 4. all-source and effect non focusing postquestions). Then, all students were instructed to memorize the characteristics of each vitamin (presented to them one row of the chart-table at a time) because a test would follow whereby each student would "have to match these characteristics to the vitamin letter printed in the left-hand column of each chart row appearing later on a printed test." Furthermore, they were told to answer the postquestions to the best of their ability. Moreover, the classroom teachers normally in charge suggested that students' scores on the posttest were important and that the scores would be available for teacher and student inspection within one month. This procedure was used to increase the chances of student cooperation in the experiment. At this point, treatment students were given 90 seconds to learn the four attributes of the first vitamin,

Vitamin A, followed by 25 seconds to answer the postquestion. Then, students were told that they would be given "one minute to memorize the characteristics of each vitamin to follow and 15 seconds to answer each question." After presenting the first seven vitamins (practice task), a one-minute rest period was provided with no talking permitted. The purpose of this practice exercise was to familiarize students with the experimental task structure and increase the chances of task clarification. After the rest period, students were again presented the same instruction. Furthermore, students were told that they "would be presented with seven more vitamins and seven more questions of the exact same type presented earlier and that because of time limitations the final vitamin test would only cover the chart information describing the last seven vitamins." Again, all students received the same instructions presented at the beginning of the practice exercise. In addition to these directions, the posttest exposure (special orienting directions) group at this time was permitted to inspect for one minute the actual test, while the postquestion emphasis (special orienting directions) group was told that their performance on the postquestions was "extremely important and correctly answering these" postquestions would "clearly improve" their "score on the" posttest. The combined intervention (orienting directions) group was provided with both additions. Subsequent to instruction, a two-minute presentation was made about the advantages of majoring in science courses while attending college. This placebo presentation was used to reduce the chances of students holding the vitamin information in their short-term memories. Finally, ample time was provided for students to complete the recognition posttest.

Sample. Two hundred ninety-nine students from 16 tenth-grade biology classes were drawn from two high schools located in Calgary, Alberta. These subjects were English-speaking and were enrolled in academic programs. None of the students had been formally taught any information about vitamins in science class since the seventh grade.

RESULTS

Table 1 and 2 contain the treatment mean scores from the posttest for the separate dependent variables - source and effect measures. The placebo-control mean scores for these two variables were 1.6 and 1.8, respectively, thus were not significantly different (correlated t-test), but were significantly lower (analysis of variance followed by Newman-Keuls) than treatment scores in 31 of the 32 matrix cells (4 postquestion treatments X 4 orienting directions X 2 dependent variables).

A four-by-four analysis of variance using repeated measures indicated significant main effects ($\alpha = .05$ for all tests of significance) of combined dependent variables for orienting directions, $F(3,253)=6.15$, and an interaction of orienting directions and postquestion treatments, $F(9,253)=3.13$. Moreover, this same analysis indicated differential student response to dependent variables, $F(1,253)=62.29$, and an interaction of posttest item type and postquestion treatment, $F(3,253)=32.69$. Subsequently, Newman-Keuls multiple range tests and correlated t-tests were used to substantiate mean differences among the 16 group cells for each dependent variable and within each group cell comparing source with effect variable performance, in accordance with the research hypotheses.

The first interaction (combining dependent variables) could clearly be attributed to the greater performance of students in the posttest exposure group or in the combined orienting direction group under the no-postquestion treatment. The main effect finding was less clear and less interesting. Here, the combined-orienting direction group was favored. The second interaction (differentiating dependent variables) indicated that students in the effect focusing postquestion treatment recognized as many or more effect and fewer source attribute items, as suggested in Table 3. In contrast, students in the other three treatments clearly recognized more source and fewer effect attributes. As predicted, main effects for the dependent variable-source favoring the source focusing postquestion treatment group were found under the four orienting conditions when comparing the source with the effect treatment groups. To a lesser degree, main effects for the dependent variable-effect favoring the effect focusing postquestion treatment group were found under the four orienting conditions when comparing the source with the effect treatments,

that is, directional magnitude was consistent with prediction and with strong hints of significance.

Finally, comparison of matched posttest items (matched or similar to students' treatment postquestions) with new posttest items (within the same category, i.e., source, effect or source and effect) failed to produce an orderly pattern of data for source, effect and all (source-effect) treatments.

DISCUSSION

Students provided no treatment postquestions, who were in the posttest exposure group or in the combined posttest exposure and postquestions emphasized group outperformed students provided with the two focusing and one non focusing postquestion treatments. This finding suggested that students who were made explicitly familiar with the recognition posttest used this extra knowledge about the criterial task during task acquisition. Yet, the presence of postquestions appeared to interfere with this criterial task information. Perhaps students just shown the posttest and not provided with a so-called study aid (i.e., postquestions) were in a better position and felt freer to identify and use their own learning strategy for memorizing the vitamin attributes. Apparently, the answering of postquestions merely obscured effective strategies useful in performing the criterial task in this case. Similar inhibitory effects were cited in McConkie's (1977) review of the literature.

The second interaction indicated that a chart-table medium facilitated the differentiation of categories to the extent that focusing behavior was much stronger than anticipated. The F ratios described in the results and t-values described in table 3 indicate that students provided with focusing postquestions in this experiment apparently paid very close attention to the target categories at the learning expense of recognizing less information in the opposite or non-target category. The learning effects produced by the postquestions were stronger than expected relative to previous studies (Ellis et al., 1980; Reynold et al., 1970; Sefkow et al., 1980; Wittrock et al., 1977) using a text medium. Indeed the apparent learning effects of the postquestions under all four orienting conditions were uniquely powerful. Perhaps the combined effect of the chart-table medium described earlier, and the introductory remarks to all students about the importance of the tasks and the nature of the postquestions and the posttest, the apparent clarity of the concept attributes and the use of a practice exercise constituted reasons for the strong focusing effects. Ironically, these conditions more often exist in classroom situations than in those experimental conditions used in most other postquestion experiments. Indeed, McConkie (1977) predicted powerful effects when students were familiarized (as they are under typical classroom conditions) with task structure. In this respect,

Sefkow et al.(1980) research using texts apparently supported McConkie's (1977) contention that frequent use of postquestions facilitates review of previously presented information.

McConkie (1977) argued that learners' retention of presented information in postquestion studies was dependent on the task structure, the task strategies adopted by the learner and the person's own schemata. Previous research suggested that the task structure in these studies was often vague in the learners' minds. As a consequence, different strategies were adopted by learners resulting in difficult-to-interpret patterns of posttest data. Second, learners often were evaluated on their retention of information presented early in the instructional treatment, thus masking potential effects on the posttests. Third, learners' expectations about the nature of the posttest were not dealt with, resulting in unknown effects on subjects' learning strategies. Most importantly, the effects of different learner perceptions about the task structure can greatly effect data patterns. The present study accounted for some of McConkie's concerns by evaluating not only the effects of varied treatments but also different learner's orientations. Indeed, providing learners with clear expectations about the posttest effected performance, as predicted. In addition, set induced by the practice exercise, as described by McConkie, was allowed some time to form in the learners' mind by not evaluating students' performance on the first seven vitamins presented in the experiment. Moreover, McConkie (1977) argued that non focused postquestions in the all question treatment in other recent studies seldom facilitated the retention of memorized bits of text information when exposure time was controlled and task ambiguities were reduced. Indeed, these principles derived from text studies can be extended to the type of chart-table medium used in the present study. Apparently, postquestions can divert attention and facilitate retention of selected information but can not necessarily increase overall performance of the critical information.

Further research needs to compare the direct and indirect learning effects of text and chart-table using a variety of information types. The effects found in the current study could be specific to the kind of information commonly displayed in chart-tables. In particular, the

display of narrative information, such as The Sea Around Us, used in many postquestion studies (Reynold et al., 1979) might produce more powerful indirect effects when presented in a chart-table. Such comparisons would clarify and differentiate information processing variables described in attending hypotheses by examining notions about reading processes from a different angle. The goal is not to identify the best medium, the goal is to understand learning activities associated with specific learner types, materials and criterial tasks, as discussed by Bransford (1979).

Table 1

Mean Scores on the Source

Portion of the Posttest Items

Special Orienting Directions	Postquestion Treatments			
	None	Source	Effect	All
No Intervention	6.2	8.1	5.0	8.1
Posttest Exposure	9.5	8.8	4.6	6.4
Postquestion Emphasis	6.1	8.5	5.3	7.4
Combined Intervention	10.4	10.2	7.1	7.6

Table 2

Mean Scores on the Effect

Portion of the Posttest Items

Special Orienting Directions	Postquestion Treatments			
	None	Source	Effect	All
None	4.5	3.9	6.2	5.6
Posttest Exposure	7.0	2.9	7.6	4.9
Postquestion Emphasis	3.7	5.2	7.1	5.8
Combined Directions	7.8	5.2	7.7	5.1

Table 3

Results of Correlated t-tests within Cells
Comparing Source with Effect Posttest Item Performance*

Special Orienting Directions	Postquestion Treatments			
	None	Source	Effect	All
None	1.83(17)	6.44(16)	1.18(17)**	4.24(16)
Posttest Exposure	3.33(12)	5.87(17)	2.39(16)	2.08(17)
Postquestion Emphasis	3.05(16)	2.10(12)	2.02(17)	1.94(16)
Combined Directions	3.81(15)	6.20(15)	.69(18)**	2.80(17)

* The above t values were significant (except where noted) and in the predicted direction (no exceptions)

** not significant

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